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Soil suitability evaluation for turmeric in Wardha district of Maharashtra

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Abstract : A case study was carried out to develop a model framework of suitability for turmeric in shrink-swell soils of Samudrapur tehsil of Wardha district. The fresh rhizome yield was correlated with soil properties and relatively better soils were identified for framework development. The agro-edaphic factors most suitable for high turmeric yield are : rainfall 900-1400 mm, temperature 28-32°C, slope 1-8 per cent, flooding no to occasional, well to moderately well drained, clay loam to clay in texture, coarse fragment less than 15 per cent, soil depth > 75 cm, pH 6.5 to 8.5, $CaCO_3$ <25 per cent, organic carbon >0.75 per cent, CEC >40 cmol(p+)kg^{-1}, ESP < 4. As per the developed criteria, pedon P6 was rated as highly suitable; P1, P2, P4, P7 , P8 as moderately suitable whereas P3, P5 and P9 were found to be marginally suitable for turmeric in this tract.

Additional key words: *Land evaluation, suitability model, shrink-swell soils*

Introduction

Turmeric (*Curcuma longa L.*) has been used as an important spice and medicinal plant in India since the time immemorial. Its cultivation is gaining importance in recent years because of its premium in the market, industrial importance and export potential. In India, it occupies nearly 15.5 lakh ha (6 per cent of the area under spices) with productivity of 3533 kg ha^{-1}. The major turmeric growing states of India are Orissa, Andhra Pradesh, Gujarat, Maharashtra, Assam, Bihar, Orissa, West Bengal, Kerala and North Eastern Hill states.

In Maharashtra, turmeric is mainly grown in Satara, Sangli, Kolhapur, Pune, Parbhani, Nanded, Wardha, Chandrapur, Nagpur, Amravati, Yavatmal and Akola districts. In Vidarbha region of Maharashtra, as many as 11 districts, with an estimated area of 1,409 ha is under turmeric cultivation and these put together produce of 11,091 metric tonnes of dried turmeric annually. The productivity of turmeric in Maharashtra as well as in Vidarbha is far below than that of other states (Andhra Pradesh, Tamil Nadu, Karnataka, and Gujarat) associated with shrink-swell soils. Although, turmeric farming fetches good return (Ramamurthy and Jagdish Prasad, 2007; Mandal *et al.* 2008; Singh *et al.* 2009) but information on proper soil-site condition for optimum productivity is virtually lacking and hence present investigation was carried out.

Materials and Methods

Nine pedons (P1 to P9) from different micro-topographic situations (basaltic landscape)with varying turmeric productivity in Waigaon (H), Dhongaon, Dongargaon, Girad and Narayanpur villages (Fig. 1) were studied (Soil Survey Division Staff 2003) and taxonomically classified (Soil Survey Staff 1995). The climate of the study area is dry sub-humid with mean annual rainfall of 1091.3 mm. Most of the rainfall (88 to 90%) is received during June to September whereas 10 to 12 per cent occurs during the remaining part of the year.

Mean annual maximum temperature is 32.6°C and mean minimum temperature is 22°C. The physical and chemical properties were estimated following standard analytical methods. The yields of the rhizome were collected from respective pedon sites and correlated with site parameters following land evaluation criteria (Sys 1985; Naidu *et al.* 2006).

Results and Discussion

The site characteristics of pedons have been given in table 1. Among the pedons, P2,P6,P7 and P8 occur on gently slopping plain, P9 on undulating plain and P1, P3, P4 and P5 on moderately sloping to undulating plain. The surface stoniness varies from 3 to 15 per cent. The pedons namely P1, P3, P4, P5, P7 and P9 belong to order Inceptisols and their effective depth ranged from 38 to 80 cm while P2, P6 and P8 (Vertisols) are more than 100 cm deep. The pedons P1, P2, P8 and P9 are moderately well drained while others are well drained. The surface horizons of these pedons are dark brown in colour but sub-surface horizons are very dark grayish brown in 10YR hue. Structurally soil peds are weak medium to moderate medium sub-angular blocky and coarse strong angular blocky The soils are clayey and the clay content ranged from 39.4 to 65.0 per cent. The bulk density varied from 1.40 to 1.50 Mg m^{-3} .The increase in dry bulk density down the profile is an indicative of the compactness due to overburden force related to clay content (Ahuja *et al.* 1988).

The soil moisture retention data (Table 1) showed that the moisture retention (w/w per cent) for Typic Haplustepts varied from 25.6 to 45.9 per cent at 33 kPa and 18.4 to 26.2 at 1500 kPa. Similarly for Vertisols, the moisture retention varied from 35.7 to 47.7 per cent at 33 kPa and from 18.2 to 28.2 per cent at 1500 kPa respectively. The moisture release characteristics of Inceptisols follow the relationship given by $Y = 76.661 X^{-0.1603}$ and $R^2 = 0.9364$, while Typic Haplusterts bears the relationship given by $Y=79.455X^{-0.1936}$ and $R^2 = 0.9626$, where Y is moisture per cent (w/w) and X denotes moisture tension in kPa.

The pH of the soil ranged from 7.3 to 8.3 and organic carbon from 0.30 to 1.35 per cent. The calcium carbonate content ranged from 6.40 to 18.32 per cent and the cation exchange capacity from 32.0 to 60.20 cmol (p+) kg^{-1}. Among the cations, exchangeable Ca was dominant cation followed by magnesium, sodium and potassium (Table 2). Base saturation ranged from 85 to 96 per cent.

The data (Table 2) indicated that Zn, Cu, Mn and Fe content in these soils varied from 0.16 to 1.65 mg kg^{-1}, 0.61 to 4.59 mg kg^{-1}, 1.31 to 18.10 mg kg^{-1} and 1.16 to 3.72 mg kg^{-1}, respectively. In general, the micronutrient cations concentration decreased with depth.

The weighted average of physical and chemical properties (Tables 3 and 4) are compared with the average rhizome yield of turmeric (Table 3). The climatic requirement, topography, soil properties were rated against the highest to lowest yield on the line of land evaluation criteria proposed by Sys (1985) and turmeric suitability (generalized criteria) proposed by Naidu *et al* (2006). The numerical soil index (X) obtained from proposed criteria correlated with fresh rhizome yield (Y, kg ha^{-1}) by the linear fit regression equation $Y = 254.06 + 57.60 X$ and $R^2 = 0.84$ The high correlation coefficient indicates that the proposed soil suitability criteria class (Table 5) are in agreement with yield. Therefore, the proposed criteria table can be used as soil-site suitability criteria for Wardha. In general, good turmeric growing soil-site characteristics should have rainfall 900 to 1400 mm, elevation 500-1000 m above MSL, temperature 28 to 32°C, slope 1 to 8 per cent, flooding no to slight, well drained to moderately well drained soils, AWC >180 mm m^{-1}; texture clay loam to clay, coarse fragment less 15 per cent, soil depth > 75 cm, $CaCO_3$ <25 per cent, pH 6.5 to 8.5, EC < 3 dSm^{-1}, organic carbon more than 0.75 per cent, CEC more than 40 cmol(p+) kg^{-1}, ESP < 4. According to the proposed criteria (frame work), P6 is highly suitable P1, P2, P4, P7 and P8 are moderately suitable and P3, P5, P9 are marginally suitable for turmeric in shrink-swell soils of dry sub humid eco-system.

Table 1. Physical properties of soils

Horizon	Depth (cm)	Particle-size distribution			Water retention (%)		AWC (w/w) (%)	Bulk density (Mg m^{-3})
		Sand	Silt	Clay	33 kPa	1500 kPa		
		(%)						
				Pedon 1 (Typic Haplustept)				
Ap	0-17	29.6	21.5	48.9	42.2	23.8	18.4	1.50
Bw	17-32	26.4	21.3	52.3	42.6	22.3	20.3	1.48
BCk	32-55	31.4	16.2	52.4	42.7	21.7	21.6	1.48
				Pedon 2 (Typic Haplustert)				
Ap	0-20	15.8	27.1	57.1	44.0	22.0	22.0	1.42
Bw1	20-40	12.6	27.8	59.6	46.7	25.8	20.9	1.44
Bw2	40-65	12.3	29.4	58.3	40.4	21.3	19.1	1.43
Bss	65-110	15.2	25.4	59.4	45.6	22.3	23.3	1.45
BCk	110-150	20.5	30.9	48.6	35.7	18.2	17.5	1.48
				Pedon 3 (Typic Haplustept)				
Ap	0-18	25.4	28.5	46.1	41.3	20.4	20.9	1.43
Bw1	18-36	20.2	31.0	47.8	42.6	22.3	20.3	1.44
2Bw2	36-64	42.1	15.8	42.1	44.8	21.0	23.8	1.44
2Bw3	64-83	41.6	15.6	42.8	44.9	23.0	21.9	1.45
BCk	83-120	48.3	20.8	39.9	38.4	18.4	20.0	1.47
				Pedon 4 (Vertic Haplustept)				
Ap	0-15	15.4	29.2	55.4	45.3	23.1	22.2	1.41
Bw1	15-30	14.3	30.2	55.5	44.9	22.0	22.9	1.42
Bw2	30-56	13.9	28.9	57.2	45.6	22.8	22.8	1.42
BC	56-80	24.1	23.2	52.7	40.3	21.1	19.2	1.43
				Pedon 5 (Typic Haplustept)				
Ap	0-15	22.8	33.4	45.8	42.9	21.1	21.8	1.42
Bw	15-30	17.2	35.2	47.6	45.9	26.2	19.7	1.45
BC	30-52	32.1	25.1	42.8	44.4	23.2	21.2	1.48

Contd...

Horizon	Depth (cm)	Particle-size distribution			Water retention (%)		AWC (w/w) (%)	Bulk density (Mg m^{-3})
		Sand	Silt	Clay	33 kPa	1500 kPa		
		(%)						
				Pedon 6 (Typic Haplustert)				
Ap	0-16	10.6	26.7	62.7	43.6	27.2	16.4	1.50
Bw	16-38	11.6	26.6	61.8	39.7	24.7	15.0	1.49
2Bss1	38-66	3.7	34.6	61.7	43.7	24.9	18.8	1.47
2Bss2	66-110	3.2	34.4	62.4	43.4	24.6	18.8	1.45
BC	110-150	8.7	33.5	57.8	40.5	25.5	15.0	1.43
				Pedon 7 (Typic Haplustept)				
Ap	0-20	16.9	31.4	51.7	40.6	23.1	17.5	1.45
Bw	20-45	15.9	30.5	53.6	41.7	24.3	17.4	1.40
BC	45-55	41.3	19.3	39.4	25.6	18.8	6.8	1.40
				Pedon 8 (Typic Haplustert)				
Ap	0-20	9.6	30.8	59.6	47.7	24.8	22.9	1.43
Bw	20-45	8.1	30.8	61.1	42.3	23.5	18.8	1.42
Bss1	45-70	7.1	27.9	65.0	44.7	24.3	20.4	1.44
Bss2	70-120	7.1	31.7	61.2	45.8	28.2	17.6	1.42
BCk	120-150	10.7	26.3	63.0	45.2	25.6	19.6	1.45
				Pedon 9 (Typic Haplustept)				
Ap	0-17	11.3	32.1	56.8	42.8	25.2	17.6	1.40
Bw	17-38	10.9	31.0	58.1	45.9	24.6	21.3	1.44

Table 2. Chemical properties of the soils

Horizon	pH 1.2.5 (soil:water)	EC (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Exchangeable cations Ca	Mg	Na	K	Sum of cations	CEC cmol	Base Saturation (%)	ESP	DTPA extractable ($mgkg^{-1}$) Zn	Cu	Mn	Fe
					cmol (p^+)kg^{-1}											
Pedon 1 (Typic Haplustept)																
Ap	7.80	0.27	0.94	10.49	24.41	10.93	0.36	0.30	36.00	41.62	86.49	0.86	1.65	3.91	16.98	3.38
Bw	8.00	0.22	0.75	13.12	27.01	13.49	0.41	0.43	41.34	46.31	89.26	0.88	0.71	3.55	8.29	2.90
BCk	7.90	0.20	0.50	15.24	26.21	19.44	0.51	0.22	46.38	50.30	92.20	1.01	0.42	1.80	4.46	2.18
Pedon 2 (Typic Haplustert)																
Ap	7.90	0.32	1.26	9.50	39.20	10.63	0.32	0.92	51.07	55.10	92.68	0.58	1.61	4.59	13.01	3.20
Bw1	7.90	0.31	0.94	9.30	38.61	11.20	0.29	0.82	50.92	56.90	89.49	0.50	0.93	3.95	9.09	3.09
Bw2	8.10	0.30	0.63	8.80	30.32	16.00	0.32	0.60	47.24	51.20	92.26	0.62	0.56	3.43	6.23	2.07
Bss	8.10	0.28	1.20	11.50	29.78	15.20	0.42	0.41	45.81	49.00	93.48	0.85	0.40	2.85	4.51	1.16
BCk	8.30	0.31	0.31	15.70	24.23	12.27	0.33	0.81	37.64	44.90	83.83	0.71	0.42	2.06	3.92	2.54
Pedon 3 (Typic Haplustept)																
Ap	7.80	0.33	1.16	14.95	20.25	13.00	0.51	1.10	34.86	38.86	89.70	1.31	1.37	4.35	15.51	3.32
Bw1	8.00	0.25	1.16	16.97	18.37	11.00	0.20	0.93	30.50	34.60	88.15	0.57	0.59	3.65	6.54	2.79
2Bw2	7.90	0.21	0.84	17.32	17.20	14.30	0.35	0.88	32.80	37.20	88.17	0.99	0.24	1.51	2.61	2.16
2Bw3	8.00	0.20	0.65	15.78	15.91	17.70	0.20	0.86	34.67	39.40	87.99	0.50	0.16	0.93	1.31	2.39
BCk	8.10	0.20	0.35	18.32	13.27	11.92	0.29	0.90	27.50	32.00	85.93	0.90	0.20	1.05	1.31	1.78
Pedon 4 (Vertic Haplustept)																
Ap	7.90	0.32	0.88	7.78	30.50	16.37	0.42	0.20	47.49	52.00	91.32	0.80	1.10	2.30	18.10	2.62
Bw1	8.00	0.30	0.78	7.60	28.29	15.80	0.39	0.42	44.90	51.10	87.86	0.76	0.48	2.03	11.53	2.12
Bw2	8.00	0.22	0.63	6.85	31.65	14.29	0.24	0.31	46.49	50.70	91.69	0.47	0.37	1.65	8.58	2.27
BC	8.00	0.27	0.50	10.85	27.27	14.26	0.20	0.27	42.00	49.00	86.93	0.40	0.28	1.25	4.17	3.15

Contd...

Horizon	pH 1.2.5 (soil:water)	EC (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Exchangeable cations Ca	Mg	Na	K	Sum of cations	CEC cmol	Base Saturation (%)	ESP	DTPA extractable ($mgkg^{-1}$) Zn	Cu	Mn	Fe
					cmol (p^+)kg^{-1}											
Pedon 5.(Typic Haplustept)																
Ap	7.70	0.50	0.90	8.04	24.39	13.49	0.81	0.08	38.77	42.30	91.65	0.91	0.83	2.27	17.50	2.17
Bw	7.90	0.22	0.87	8.45	23.10	11.49	0.73	0.62	35.94	40.10	89.85	0.54	0.38	2.15	10.65	1.87
BC	8.00	0.24	0.85	14.15	19.24	10.60	0.49	0.35	30.68	36.00	85.22	0.97	0.29	1.11	5.25	1.59
Pedon 6 (Typic Haplustert)																
Ap	7.40	0.29	1.33	6.54	34.68	20.02	1.10	0.71	56.51	60.00	94.18	1.83	0.60	1.85	13.28	2.68
Bw	7.60	0.25	1.35	6.57	31.31	17.99	0.61	0.42	50.34	54.70	92.01	0.78	0.36	1.46	7.14	2.37
2Bss1	7.50	0.27	0.97	6.93	29.47	17.15	0.42	0.34	47.98	58.00	82.72	0.58	0.24	0.95	5.29	2.15
2Bss2	7.49	0.27	0.94	7.30	28.92	20.31	0.33	0.28	49.84	60.20	81.46	0.46	0.20	0.88	4.70	1.85
BC	7.32	0.29	0.92	7.50	24.71	14.89	0.21	0.21	40.02	44.20	90.54	0.47	0.28	0.79	5.61	2.51
Pedon 7 (Typic Haplustept)																
Ap	7.90	0.41	0.91	6.98	27.40	14.79	0.51	0.41	43.11	45.00	95.84	0.91	0.81	2.23	17.22	2.48
Bw	8.00	0.36	0.73	8.37	27.69	16.78	0.40	0.39	45.26	51.30	88.22	0.76	0.34	2.53	13.70	2.30
BC	8.10	0.31	0.62	13.46	22.34	10.37	0.42	0.22	33.40	36.00	92.77	0.61	0.37	0.65	5.47	3.67
Pedon 8 (Typic Haplustert)																
Ap	8.00	0.28	0.85	7.03	28.96	17.23	0.53	1.56	48.22	54.00	87.44	0.90	0.55	2.27	14.75	2.52
Bw	8.10	0.20	0.63	7.97	32.83	14.71	0.50	1.52	49.56	58.00	85.44	0.86	0.34	1.79	9.28	2.35
Bss1	8.00	0.23	0.57	8.75	27.40	19.20	0.55	0.90	48.05	52.40	91.69	0.85	0.34	1.09	9.31	3.72
Bss2	7.90	0.21	0.49	9.23	29.87	17.48	0.50	0.86	48.71	54.30	89.70	0.92	0.30	0.61	8.84	3.10
BCk	8.00	0.54	0.30	9.72	28.37	12.37	0.42	0.80	41.96	47.80	87.78	0.87	0.40	0.87	7.69	2.89
Pedon 9 (Typic Haplustept)																
Ap	8.10	0.31	0.99	8.27	37.61	10.50	1.37	0.87	50.35	54.32	92.69	2.52	0.76	3.21	14.54	2.89
Bw	8.00	0.26	0.62	6.40	31.30	13.10	1.43	0.55	46.38	53.30	87.01	2.68	0.55	2.30	9.84	2.62

Table 3. Physical properties (weighted average) of soils

Pedon No.	Depth (cm)	Sand	Silt	Clay	AWC (%)	BD (Mg m^{-3})	Yield Kg ha^{-1}
			(%)				
P1	55	29.37	19.33	51.29	20.23	1.48	3450
P2	150	15.83	28.08	56.02	20.85	1.44	3950
P3	120	38.45	18.54	42.98	21.41	1.44	2832
P4	80	17.31	27.49	55.19	21.59	1.42	4000
P5	52	24.62	30.29	45.05	20.98	1.45	3050
P6	150	6.63	33.51	55.79	16.96	1.45	4500
P7	55	20.84	28.77	50.32	17.30	1.41	3940
P8	150	8.27	29.71	61.94	19.37	1.43	3760
P9	38	11.07	31.49	57.51	19.64	1.42	2056

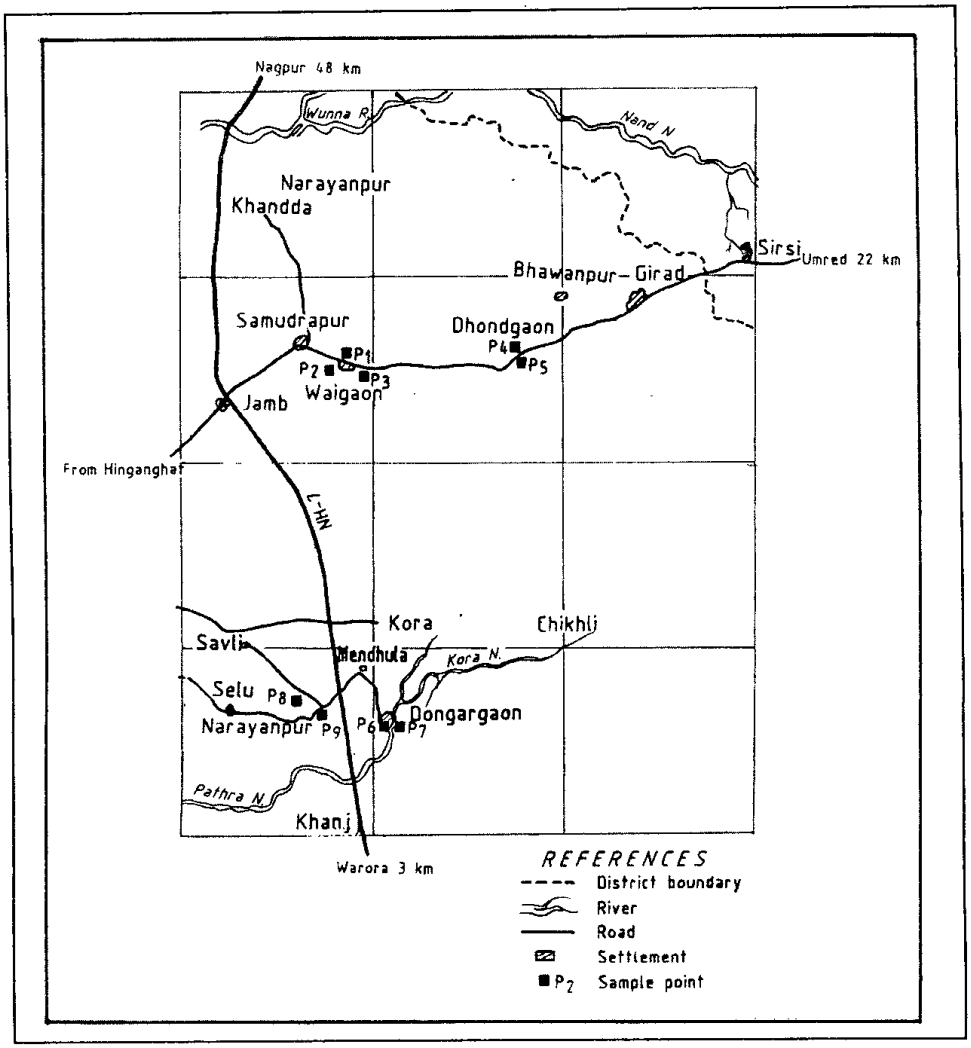

Fig. 1. Observation site in Wardha District

Table 4. Chemical properties of soils (weighted average)

Pedon No.	Depth (cm)	pH (1.2.5)	EC dSm^{-1}	O.C (%)	$CaCO_3$ (%)	Exchangable cations Ca	Mg	Na	K	Sum of cations	CEC	Base Saturation (%)	ESP	DTPA – extractable (mg kg^{-1}) Zn	Cu	Mn	Fe
						cmol $(p^+)kg^{-1}$											
P_1	55	7.89	0.22	0.70	13.19	25.87	15.18	0.43	0.30	41.79	46.53	89.63	0.92	0.87	1.92	9.37	2.74
P_2	150	8.10	0.30	0.84	12.20	31.00	13.40	0.34	0.67	45.24	50.14	90.06	0.69	0.66	3.11	6.38	2.21
P_3	120	7.97	0.22	0.75	16.97	16.41	13.72	0.30	0.92	31.42	35.80	87.59	0.86	0.41	2.02	3.69	2.34
P_4	80	7.98	0.26	0.66	8.36	29.49	14.95	0.28	0.29	45.21	50.50	89.45	0.56	0.50	1.72	9.59	2.57
P_5	52	7.88	0.30	0.91	10.74	21.83	11.69	0.65	0.35	34.53	39.00	88.41	1.11	0.47	1.74	10.36	1.83
P_6	150	7.45	0.27	1.06	7.00	27.60	17.3	0.42	0.32	45.50	52.37	84.10	0.65	0.29	1.05	6.32	2.16
P_7	55	7.98	0.36	0.77	8.79	26.62	14.89	0.44	0.36	42.32	46.22	91.81	0 78	0.51	2.07	13.48	2.61
P_8	150	8.08	0.28	0.53	8.74	29.51	16.24	0.47	1.05	47.15	53.26	88.27	0.89	0.36	1.16	9.53	3.16
P_9	38	8.04	0.28	0.79	7.23	34.12	11.93	1.40	0.69	48.15	52.75	89.55	2.60	0.64	2.70	11.94	2.74

Table 5. Soil-site characteristics for turmeric

Land characteristics	Class degree of limitation and rating scale				
	S1		S2	S3	Not suitable
	0	1	2	3	4
	10 95	85	60	40	25
Climatic requirement					
Rainfall (mm)	1400-1100	1100-900	900-700	700-500	<500
Elevation	500-800	800-1000	1000-1500	1500-2000	>2000
Temperature(^{0}C)	28-32		20-27 33-37	10-19 38-45	<10; >40
Topography					
Slope (%)	1-3	3-8	8-15	15-20	>20
Wetness(W)					
Flooding	F0	F1	F1		
Drainage	Well	Mod. well	Imperfect	Poor, excessive	Poorly drained or excessively drained
Physical soil characteristics(s)					
AWC	>200	180-200	160-180	160-140	140-120; <120
Texture/structure	cl-l	l-sicl	c >50	sl; c>50-60	c >60
Coarse fragment (volume %)	<5	5-15	15-20	20-40	>40
Soil depth(cm)	>75	50-75	25-50	10-25	<10
$CaCO_3$ (%)	0-20	20-25	25-40	40-50	>50
Soil fertility characteristics (F)					
pH	6.5-7.5	7.5-8.5	8.5-9.5	9.5-10	>10
EC (dS m^{-1})	<1	1-3	3-5	5-7	>7
Organic Carbon (%)	>1	1-0.75	0.75-0.5	0.5-0.25	<0.25
Available NPK	High	Mod. high	Medium	Low	very low
CEC	>50	50-40	40-30	30-20	<20
ESP	<1	1-4	4-8	8-15	>15

Table 6. Soil-site characteristics for turmeric[1]

Soil-site characteristics	P1	P2	P3	P4	P5	P6	P7	P8	P9
				Topography (t)					
Slope (%)	95	100	95	95	95	100	100	100	100
				Wetness (W)					
Flooding	95	95	95	100	100	100	100	100	95
Drainage	95	95	100	100	100	100	100	95	95
				Physical soi characteristics (S)					
AWC	100	100	100	100	100	100	100	100	100
Texture/Structure	85	85	80	85	80	85	85	85	85
Soil depth (cm)	90	100	100	100	90	100	90	100	75
$CaCO_3$(%)	100	100	100	100	100	100	100	100	100
				Soil fertility characteristics (F)					
pH	95	95	93	93	95	100	93	95	95
EC (dS m^{-1})	100	100	100	100	100	100	100	100	100
Organic carbon (%)	95	100	100	93	93	100	93	90	95
CEC	95	100	75	100	85	100	95	100	100
				Alkalinity					
ESP	100	100	100	100	95	100	100	100	87
Land Index (X)	50.98	66.07	45.65	63.31	44.24	77.06	56.98	62.59	40.96
Suitability class	S_2	S_2	S_3	S_2	S_3	S_1	S_2	S_2	S_3

Note : Corresponding climatic rating *i.e.* 100 is integrated in the evaluation of characteristics above and then land index values are calculated. S1- X=100-75, S2- X=75-50, S3-X=50-25,N-X=25-0.
[1]Sys (1985)

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